"Designing of Antenna For Aircraft Landing"

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CERTIFICATE

This is to certify that the work titled **"DESIGINING OF ANTENNA FOR AIRCRAFT LANDING"** is submitted by **ADITYA KUMAR (071156), ARUNIMA VED (071065), RAJAT MEHROTRA (071132), SURBHI MADAN (071051)** in partial fulfillment for the award of degree of Bachelor of Technology in Jaypee University of Information Technology, WAKNAGHAT, SOLAN has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

Signature of Supervisor:

Name of Supervisor: Prof. Sunil V.Bhooshan

Designation: Professor (HOD)

Date: May 9, 2011

ACKNOWLEDGEMENT

Nothing In This World Will Take Place Of Persistence. Talent Will Not; Nothing Is Uncommon Then Unsuccessful Man With Talent, Genius Will Not; Unrecorded Genius Is Almost A Proverb, Education Alone Will Not ; The World Is Full Of Derelicts, Persistence And Determination Are Omnipotent"

We wish to express our gratitude and indebtness to our project guide Prof. Dr. Sunil V. Bhooshan for his encouragement, guidance and valuable assistance which helped us to complete this project successfully.

We are at loss of words to express our deep gratitude towards our guide who made us realize the fact that stumbling blocks were in fact stepping stones to success. He motivated us to take this project as a challenge and come out with flying colours.

We would also like to thank Dr. Pradeep Kumar for their valuable suggestions which helped us to complete the project work in time.

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ABSTRACT

In this project we aim at developing an antenna design which will give a precision guidance to aircraft at the time of landing and we are trying to keep the power same throughout its glide path so that there is a equal distribution of power all over the path.

As we know as the distance is less the power receive is more so when the aircraft is at a far distance from the runway it receives less power as compared to the case when the aircraft is nearer due to which enough power get wasted.

So we need to get the desired radiation pattern which will give precision guidance to the aircraft and there should be same power distribution.

Basically when we need to deal with the desired radiation pattern we can't get that with the single element of antenna. So we here need a system of similar antennas similarly oriented which make use of wave interference phenomena that occur between the radiation from different elements of antenna to form an antenna array.

So in this project we deal with the various kind of wave propagation and their effect on the power on the receiving antenna. Further we calculated the net power and then design the antenna through fourier analysis to meet the desired radiation pattern as calculated earlier.

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Chapter 1

Antennas

1.1 Introduction

Antennas, or aerials, are structures designed to radiate (or receive) electromagnetic radiation in a given direction or directions. An **antenna** is an electrical device which couples radio waves in free space to an electrical current used by a radio receiver or transmitter. In reception, the antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage that the radio receiver can amplify.

Alternatively, a radio transmitter will produce a large radio frequency current that may be applied to the terminals of the same antenna in order to convert it into an electromagnetic wave (radio wave) radiated into free space.

An antenna is defined as an object, often a metallic wire or rod, designed to radiate or receive electromagnetic radiation. Additionally, antennas are required to optimize the radiation in some directions, while suppressing it in others. Antennas may take several different forms, depending on the particular need. Examples include wire, loop, and horn antennas.

Usually antennas operate in air or vacuum (as in the case of antennas used in outer space) but may be also operated in submarine mode, from under water. As in the case of a half-wave dipole, when an antenna is used in the radiating mode, the antenna is excited by a source of electromagnetic waves, and the antenna radiates the radiation as efficiently as possible. In this chapter we will look at the fundamentals of antennas and those concepts which will be useful to a communication engineer.

When an antenna radiates, it does so directionally. That is it radiates more in one direction than another one. The *far field* electromagnetic fields, in the spherical coordinate system and in phasor notation, are invariably of the type

$$E(r,\theta,\phi) = \frac{Kf_n(\theta,\phi)}{r}e^{-jkr}$$
$$H(r,\theta,\phi) = \frac{Kf_n(\theta,\phi)}{Z_0 r}e^{-jkr}$$

Where

- K is a complex constant;
- $f_n(\theta,\Phi)$ is a real function whose maximum value for all values of θ and Φ
- $Z_0 = 377\text{ohm} = 120\pi$, the intrinsic impedance of free space and
- k is the free-space propagation constant.

In the far field, the radiation electric and magnetic fields vary as $1/r$

1.2 Power Radiated

To determine the power radiated by an antenna, we start with the instantaneous Poynting vector (vector power density) defined by

$$\mathbf{P} = \mathbf{E} * \mathbf{H} \qquad (\text{V/m} * \text{A/m} = \text{W/m}^2)$$

The directions of E and H are such that the electric field is perpendicular to the magnetic field, and both are perpendicular to $\mathbf{a}_r$. And furthermore, the Poynting vector, $\mathbf{P} = \mathbf{E}\times\mathbf{H}$ is in the direction of $\mathbf{a}_r$. That is

$$\mathbf{P} = P(r,\theta,\phi)\mathbf{a}_r \quad (\text{W/m}^2)$$

And if α is the angle (which is $\pi/2$) from the electric field vector to the magnetic field vector, then

$$P = \frac{1}{2} EH^* \sin \underset{(\pi/2)}{\alpha} = \frac{1}{2}\left[\frac{Kf_n(\theta,\phi)}{r}e^{-jkr}\right]\left[\frac{Kf_n(\theta,\phi)}{Z_0 r}e^{-jkr}\right]^* = \frac{|K|^2}{2Z_0 r^2}\left[f_n(\theta,\phi)\right]^2$$

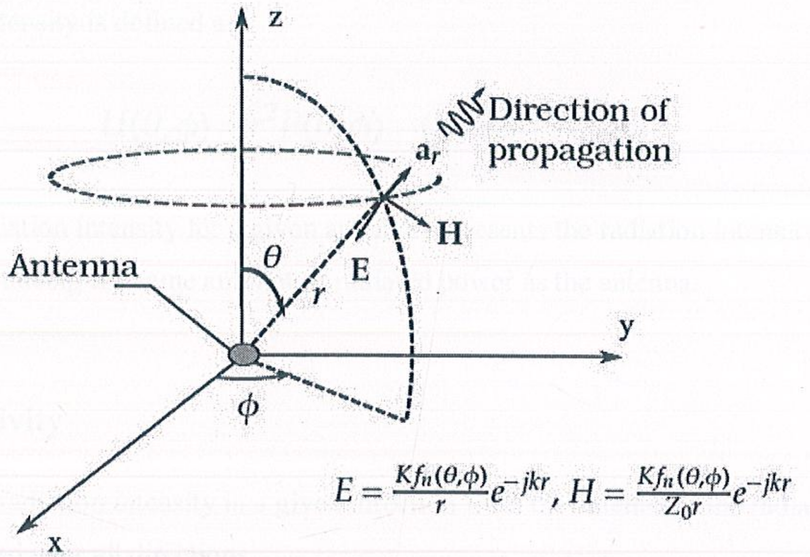

Fig 1.1 Far fields of an antenna

$$E_n(r,\theta,\phi) = \frac{E(r,\theta,\phi)}{E(r,\theta,\phi)\big|_{\text{maximum value}}} = \frac{\frac{Kf_n(\theta,\phi)}{r}e^{-jkr}}{\frac{K}{r}e^{-jkr}} = f_n(\theta,\phi)$$

$$P_n(r,\theta,\phi) = \frac{P(r,\theta,\phi)}{P(r,\theta,\phi)\big|_{\text{maximum value}}} = \left[f_n(\theta,\phi)\right]^2$$

Both these functions are of course, unitless. We may recover the electric field and the power pattern function from

$$E(r,\theta,\phi) = E_{\max} E_n(r,\theta,\phi) \quad (\mathrm{V/m})$$
$$P(r,\theta,\phi) = P_{\max} P_n(r,\theta,\phi) \quad (\mathrm{W/m^2})$$

The radiation intensity is defined as

$$U(\theta,\phi) = r^2 P(\theta,\phi) \quad (\text{Units= W/str})$$

The average radiation intensity for a given antenna represents the radiation intensity of a point source producing the same amount of radiated power as the antenna.

1.3 Directivity

The ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions.

The directivity of an antenna is defined by the formula

$$D = \frac{\text{Maximum power density radiated } (\mathrm{W/m^2})}{\text{Average power density radiated } (\mathrm{W/m^2})}$$

The directivity of an isotropic radiator is $D(\theta_0, \Phi_0) = 1$.
The maximum directivity is defined as $[D(\theta_0, \Phi_0)]\max = Do$.
The directivity range for any antenna is $0 \le D(\theta_0, \Phi_0) \le Do$.

The maximum power density radiated, will be in some specific direction given by (θ_0, Φ_0). The average power radiated by an antenna, P_{av}, is

$$P_{av} = \frac{\text{Total power radiated (W)}}{4\pi r^2(\text{=area of the surface of a sphere})} \quad (\text{W/m}^2)$$

and the total power radiated is an integral of the Poynting vector over the same sphere

$$P_T = \underset{\text{sphere of radius } r}{\oiint} P(r,\theta,\phi)\ \underbrace{r^2 \sin\theta d\theta d\phi}_{\text{an element of area}}$$

(if we examine the term

$$\underbrace{r^2}_{\text{"Area"}}\ \underbrace{\sin\theta d\theta d\phi}_{\text{"Angle"}\times\text{"Angle"}} = r^2 d\Omega$$

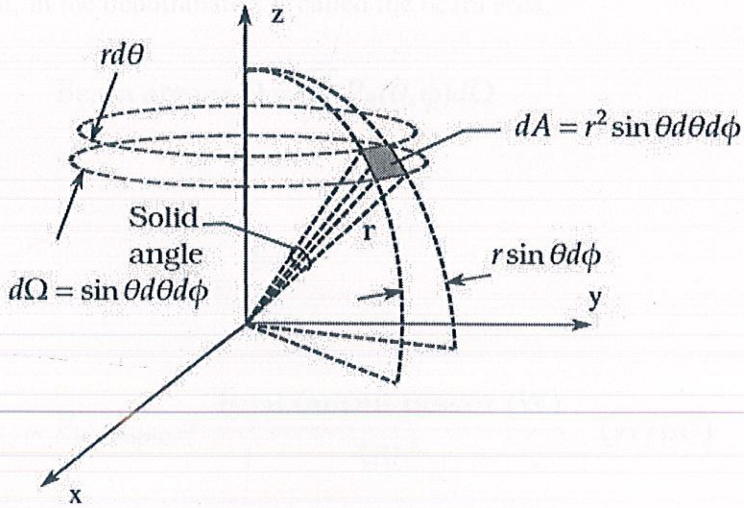

Fig 1.2 Definition of a solid angle

the area r_2 sinθ dθ dΦ subtends a "solid angle" dΩ = sinθ dθ dΦ at the centre of the sphere, where the term dΩ in the equation is defined as the *beam solid angle* .

Therefore if Ω is the solid angle subtended at the centre of the sphere, then

$$P_T = \oiint_{\text{sphere of radius } r} P(r,\theta,\phi) r^2 d\Omega$$

$$= \oiint P_{\max} P_n(\theta,\phi) r^2 d\Omega$$

$$P_{\text{ave}} = \frac{\oiint P_{\max} P_n(\theta,\phi) r^2 d\Omega}{4\pi r^2} = \frac{1}{4\pi} \oiint P_{\max} P_n(\theta,\phi) d\Omega$$

Therefore, the directivity is

$$D = \frac{P_{\max}}{\frac{1}{4\pi} \oiint P_{\max} P_n(\theta,\phi) d\Omega} = \frac{4\pi}{\oiint P_n(\theta,\phi) d\Omega}$$

the term on the right, in the denominator, is called the beam area,

$$\text{Beam area} = \Omega = \oiint P_n(\theta,\phi) d\Omega$$

So,

$$D = \frac{4\pi}{\Omega}$$

$$P_{\text{av}} = P_{\text{isotropic}} = \frac{\text{Total output power (W)}}{4\pi r^2} \quad (\text{W/m}^2)$$

So if P_{max} is the power density at a distance r in the direction of the main beam, (θ_0, Φ_0), then

$$\boxed{P_{\max} = DP_{\text{isotropiuc}}}$$

1.4 Antenna Efficiency

The efficiency of an antenna relates the power delivered to the antenna and the power radiated or dissipated within the antenna. A high efficiency antenna has most of the power present at the antenna's input radiated away. A low efficiency antenna has most of the power absorbed as losses within the antenna, or reflected away due to impedance mismatch.

The losses associated within an antenna are typically the conduction losses (due to finite conductivity of the antenna) and dielectric losses (due to conduction within a dielectric which may be present within an antenna).

The antenna efficiency (or radiation efficiency) can be written as the ratio of the radiated power to the input power of the antenna:

$$\varepsilon_R = \frac{P_{radiated}}{P_{input}}$$

Efficiency is ultimately a ratio, giving a number between 0 and 1. Efficiency is very often quoted in terms of a percentage

For example, an efficiency of 0.5 is the same as 50%. Antenna efficiency is also frequently quoted in decibels (dB); an efficiency of 0.1 is 10% or (-10 dB), and an efficiency of 0.5 or 50% is -3 dB.

Efficiency is one of the most important antenna parameters. It can be very close to 100% (or 0 dB) for dish, horn antennas, or half-wavelength dipoles with no lossy materials around them. Mobile phone antennas, or wifi antennas in consumer electronics products, typically have efficiencies from 20%-70% (-7 to -1.5 dB). The losses are often due to the electronics and materials that surround the antennas; these tend to absorb some of the radiated power (converting the energy to heat), which lowers the efficiency of the antenna. Car radio antennas can have a total antenna efficiency of -20 dB (1% efficiency) at the AM radio frequencies; this is because the antennas are much smaller than a half-wavelength at the operational frequency, which greatly lowers antenna efficiency. The radio link is maintained because the AM Broadcast tower uses a very high transmit power.

1.5 Antenna Gain

The term **Gain** describes how much power is transmitted in the direction of peak radiation to that of an isotropic source.

It is basically the ratio of the antenna radiated power density at a distant point to the *total antenna input power* (*Pin*) radiated isotropically.

Thus, the antenna gain, being dependent on the total power delivered to the antenna input terminals, accounts for the ohmic losses in the antenna while the antenna directivity, being dependent on the total radiated power, does not include the effect of ohmic losses.

$$G(\theta,\phi) = \frac{4\pi U(\theta,\phi)}{P_{in}} = \frac{U(\theta,\phi)}{\frac{P_{in}}{4\pi}}$$

A gain of 3 dB means that the power received far from the antenna will be 3 dB (twice as much) higher than what would be received from a lossless isotropic antenna with the same input power.

The gain of a real antenna can be as high as 40-50 dB for very large dish antennas (although this is rare). Directivity can be as low as 1.76 dB for a real antenna, but can never theoretically be less than 0 dB. However, the peak gain of an antenna can be arbitrarily low because of losses or low efficiency. Electrically small antennas (small relative to the wavelength of the frequency that the antenna operates at) can be very inefficient, with gains lower than -10 dB (even without accounting for impedance mismatch loss).

1.6 Effective Aperture

Antennas are reciprocal elements: the direction in which they radiate best, is the same direction in which they receive best. Thus if an antenna has its main beam in the direction (θ_0, Φ_0), then when used as a receiving antenna it registers maximum radiation from the same direction, namely, the direction (θ_0, Φ_0)

A useful parameter calculating the receive power of an antenna is the effective area or effective aperture. Assume that a plane wave with the same polarization as the receive antenna is incident upon the antenna. Further assume that the wave is travelling towards the antenna in the antenna's direction of maximum radiation (the direction from which the most power would be received).

The Poynting vector magnitude of the plane wave is P watts/m^2. Hence to trap power (watts), the antenna must have what is called an *effective aperture,* A_e(m^2).

Therefore the received power, P_r, is

$$P_r = A_e P$$

Hence, the effective area simply represents how much power is captured from the plane wave and delivered by the antenna. This area factors in the losses intrinsic to the antenna (ohmic losses, dielectric losses, etc.).

It turns out that the effective aperture and directivity are linked by

$$A_e = \lambda^2 \frac{D}{4\pi}$$

for every antenna. With this formula we can derive the power received by an antenna when it is transmitted by another.

Effective aperture or effective area can be measured on actual antennas by comparison with a known antenna with a given effective aperture, or by calculation using the measured gain

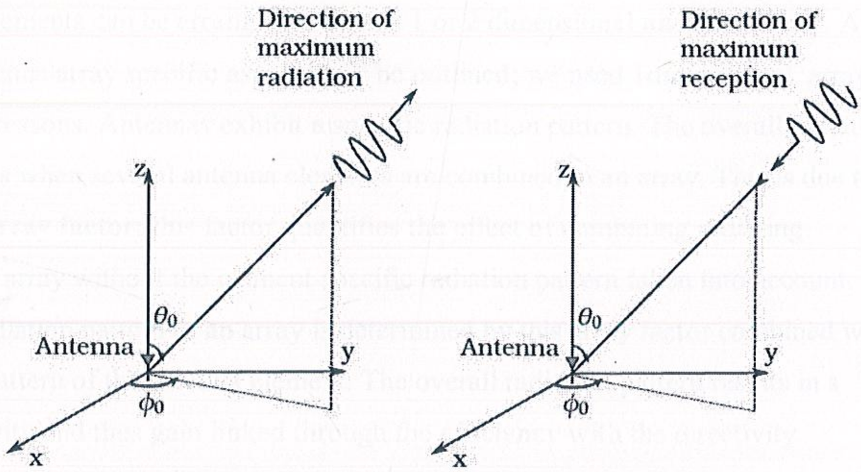

Fig 1.3 Reciprocity property of antennas

Chapter 2

Antenna array

2.1 Introduction

When we need to deal with the desired radiation pattern we can't get that with the single element of antenna. So we here need a system of similar antennas similarly oriented which make use of wave interference phenomena that occur between the radiation from different elements that what we call it an **Antenna array.**

The antenna elements can be arranged to form a 1 or 2 dimensional **antenna array**. A number of antenna array specific aspects will be outlined; we used 1dimensional arrays for simplicity reasons. Antennas exhibit a specific radiation pattern. The overall radiation pattern changes when several antenna elements are combined in an array. This is due to the so called **array factor**: this factor quantifies the effect of combining radiating elements in an array without the element specific radiation pattern taken into account. The overall radiation pattern of an array is determined by this array factor combined with the radiation pattern of the antenna element. The overall radiation pattern results in a certain directivity and thus gain linked through the **efficiency** with the directivity. Directivity and gain are equal if the efficiency is 100%.

2.2 Topology of Antenna Array

Arrays can be designed to radiate in either **broadside** i.e. radiation perpendicular to array orientation (the z axis in figure) or **end fire** i.e. radiation in the same direction as the array orientation (the y axis in figure). We will focus on broadside arrays and only radiation in the z direction is considered. This allows for easy transformation to 2dimensional planar arrays with the elements in the xy plane. For linear arrays the radiation patterns given below are a cross section in the yz plane. Actually, the

3dimensional radiation pattern of a linear array is a rotation around the y axis of the patterns given.

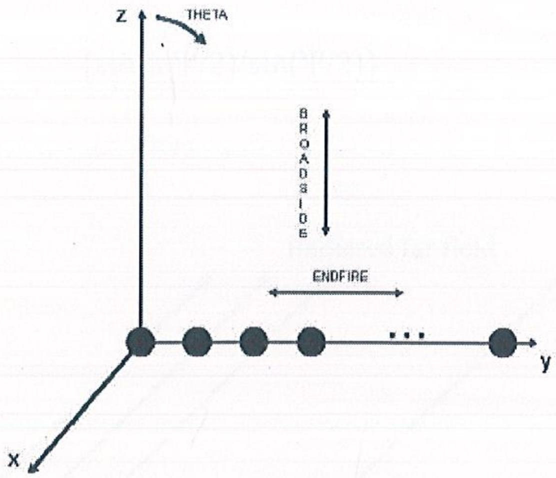

Fig 2.1 Topology of Antenna Array

2.3 Array factor

The array factor depends on the number of elements, the element spacing, amplitude and phase of the applied signal to each element. The number of elements and the element spacing determine the surface area of the overall radiating structure. This surface area is called **aperture**. A larger aperture results in a higher gain. The **aperture efficiency** quantifies how efficient the aperture is used.

Considering an array of n antenna elements in which total Phase difference is

$$\Psi=\beta d\cos\phi+\alpha$$

Where,

α –phase angle

Total Path difference is

$$\beta d = (2\Pi/\lambda)d$$

$$E_t = E_o \; (1 + e^{j\Psi} + e^{2j\Psi} + e^{3j\Psi} + \ldots\ldots + e^{(n-1)j\Psi})$$

$$E_t = E_o \, e^{(n-1/2)j\Psi} \; \{\sin(n\,\Psi/2)/\sin(\Psi/2)\}$$

So Array Factor

$$\{\sin(n\,\Psi/2)/\sin(\Psi/2)\}$$

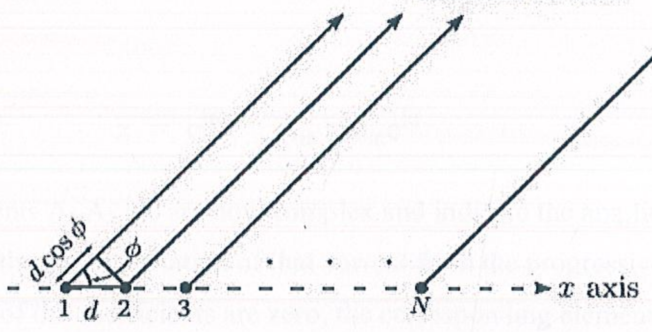

Fig 2.2 Linear Array

2.4 The mathematics of Antenna arrays

The binomial array is one example of a large class of linear arrays having special current distributions by means of which the radiation patterns can be made to have almost any prescribed shape. Linear Arrays can be represented as polynomials and this representation becomes a useful tool in the analysis and synthesis of antenna arrays.

For a general linear array of equally spaced elements the relative amplitude of the radiated field strength is given by

$$|E| = |a_o e^{j\alpha}{}_0 + a_1 e^{j\psi+j\alpha} + a_2 e^{j2\psi+j\alpha} + \ldots\ldots + a_{n-2} e^{j(n-2)\psi+j\alpha} + e^{j(n-1)\psi}|$$

Where

$$\psi = \beta d \cos\phi + \alpha \quad , \quad \beta = \frac{2\Pi}{\lambda}$$

In the above expression d is the spacing between elements. The coefficients a_o, a_1, a_2,etc are proportional to the current amplitudes in the respective elements. α is the progressive phase shift (lead) from left to right;α_1, α_2,etc are the deviation from the progressive phase shift. The above expression may be written as

$$|E| = |A_o + A_1 z + A_2 z^2 + \ldots\ldots\ldots\ldots\ldots + A_{n-2} z^{n-2} + z^{n-1}|$$

Where

$$z = e^{j\psi} \qquad A_m = a_m e^{j\alpha}$$

The coefficients A_1, A_2,etc are now complex and indicate the amplitude of current in each element and the phase deviation of that current from the progressive phase shift of the array. If any of the coefficients are zero, the corresponding element of the array will be missing, and the actual separation between adjacent elements can be greater than the "apparent separation" d. The apparent separation is the greatest common measure of the actual separations.

The following fundamental theorems are the foundations for the method:

THEOREM I: Every linear array with commensurable separations between the elements can be represented by a polynomial, and every polynomial can be interpreted as a linear array.

Since the product of two polynomials is a polynomial, a corollary to thermo I is:

THEOREM II: There exists a linear array with a space factor equal to the product of the space factors of two linear arrays.

THEOREM III: The space factor of a linear array of n apparent elements is the product of (n-1) virtual couplets with their null points at the zeros of E.

The space factor of an array is defined as the radiation pattern of a similar array of nondirective or isotropic elements. The degree of the polynomial which represents an array is always one less than the apparent number of elements. The actual number of elements is at most equal to the apparent number. The total length of the array is the product of the apparent separation and the degree of the polynomial.

Consider a simple two element array in which the currents in the elements are equal in magnitude .The relative radiation field strength is represented by

$$|E|=| 1 + z |$$

Where,

$$z=e^{j(\beta d \cos\phi + \alpha)}$$

Making use of Theorem II, a second array can be constructed which will have a radiation pattern that is square of that given by the above equation , that is,

$$|E|=| 1 + z |^2 = |1 + 2z + z^2|$$

It is seen that the array that will produce this pattern is a three element array having the current ratios

$$1 : 2 : 1$$

The current in the center element will lead the left- handed element by α, and the current in the right hand element will lead that in the left-hand element by 2α.

When the element spacing d is not greater than $\lambda/2$,such an array produces a pattern with no secondary lobes .However the principal lobe is considerably broader than that produced by a uniform array having the same number of elements. An array having a narrower principal lobe than that given by the binomial distribution and smaller secondary lobes than that given by the uniform distribution can be obtained by raising the polynomial of the uniform array of n elements (where n>2) to any desired power.

For an n-element uniform array

$$|E|=|1+ z + z^2 + \ldots\ldots\ldots\ldots + z^{n-1}|$$

When n, the number of elements, is large the ratio of the principal maximum to the first secondary maximum is approximately independent of n.

Where,

$$Z=e^{j\psi} \qquad \psi = \beta d\cos\phi + \alpha$$

Since ψ is real, $j\psi$ is a pure imaginary, and the absolute value of z is always unity. Plotted in the complex plane, z is always on the circumference of the unit circle. As ϕ increases from 0 to 180 degrees ψ decreases from $\beta d + \alpha$ to $-\beta d + \alpha$ and z moves in clockwise direction .Because of symmetry the range of ϕ to be considered is from zero to 180 degrees. Thus the range of ψ described by z is $\psi=2\beta d$ radians.

For example, for a separation between elements of $\lambda/4$,ψ varies through Π radians as ϕ goes from 0 to 180 degrees, and z describes a semicircle.(z retraces its path to the starting point as ϕ goes from 180 to 360 degrees, and the pattern is symmetrical about the 0-180 degree line).For $d=\lambda/2$ the range of ψ is 2Π radians and z describes a complete circle as ϕ varies from zero to 180 degrees. If d is greater than $\lambda/2$, the range of ψ is greater than 2Π,and z will overlap itself.

2.5 Antenna Synthesis

It is a simple and straightforward job to compute the radiation pattern of an array having specified configuration and antenna currents. A somewhat more difficult problem is the design of an array to produce a prescribed radiation pattern .Making use of Fourier analysis, the methods explained may be extended to accomplish this result.

It is covinent to consider to consider an array having an odd number of elements with a certain symmetry of current distribution about the center element. The polynomial for an array with n= 2m+1 elements is

$$|E|=|A_o+A_1z+A_2z^2+A_mz^m+A_{m+1}z^{m+1}+A_{2m}z^{2m}|$$

Now the absolute value of z is always unity, so the above equation can be divided by z^m without changing the value of |E|.T hat is

$$|E|=|A_oz^{-m}+A_1z^{-m+1}+\ldots+A_{m-1}z^{-1}+A_mz^m+A_{m+1}z+\ldots\ldots+A_{2m}z^m|$$

It is now specified that the currents in corresponding elements on the either side of the center element be equal in magnitude, but that the phase of the left – side element shall lag that of the center element by the same amount that the corresponding right-side element leads the center element(or vice-versa).That is , the coefficients of corresponding elements are made complex conjugates with

$$A_m=a_o \qquad A_{m-k}=a_k-jb_k \qquad A_{m+k}=a_k+jb_k$$

The expression for | E | is now

$$|E|=2[\frac{1}{2}a_o+a_1\cos\psi+\ldots+a_m\cos m\psi-(+b_1\sin\psi+\ldots+b_m\sin m\psi)]$$

$$=2\{\frac{a}{2}+\sum_{k=1}^{k=m}[a_k\cos k\psi+(-b_k)\sin k\psi]\}$$

These are the first 2m+1terms of a fourier series in which the coefficients of the cosine terms are the a_k's, and the coefficients of the sine terms are(-b_k's).Now any radiation pattern specified as a function f(ψ) may be expanded as a Fourier Series with an infinite number of terms. Such a pattern may be approximated to any desired accuracy by means of finite series. When this is done the required current distribution of the array can be written down directly. From the theory of fourier series ,this approximation is the least-mean square sense; i.e., the mean- square difference between the desired and the approximate pattern for ψ from 0 to 2Π is minimized.

Chapter 3

Radio wave Propagation

3.1 Introduction

Radio wave propagation describes how radio waves behave when they are transmitted, or are propagated from one point on the Earth to another. They may reach the receiving antenna over any of many possible propagation paths.

Propagation of radio waves may take place in the following ways:

1. Ground Wave Propagation
2. Sky wave propagation

Ground wave propagation is the radio wave which results because of the presence of the ground or earth. The ground wave may be classified further into two categories:

1. Space wave
    1. Direct wave
    2. Ground reflected wave
2. Surface wave

3.1.1 Space wave:

The space wave is made up of direct wave, the signal that travel direct path from transmitter to receiver, When the receiver and transmitter are within line-of sight(LOS) of each other, the signal travels by 'straight line paths' between the two. And the ground reflected wave, which is signal arriving at the receiver after being reflected from the surface of earth i.e. modifying the direct wave. Therefore, to calculate space wave both direct wave and reflected wave (p_d and p_r) both are consider.

3.1.2 Surface Wave:

In free space, wave travels in straight line, but in the presence of earth and its atmosphere, the path of the wave gets altered. Frequencies below high frequency region travel along curvature of the earth. This due to the diffraction effect and wave guide effect which uses earth surface and lowest ionised surface of atmosphere.

The surface wave is that part of the radio wave which travels along the surface of the earth. The wave is supported at the lower edge by the ground. Such propagation take place when the transmitting and receiving antenna's are close to the surface on the earth. Surface waves are utilized for broadcasting purpose.

Energy is abstracted from surface wave to supply the losses in the ground, so the attenuation of this wave is directly affected by the constants of the earth along which it travels. When both antennas are located right at the earth surface the direct and ground reflected terms in the space wave cancel each other and transmission is entirely by means of surface wave.

3.1.3 Sky wave propagation (Ionospheric waves):

Waves in the HF range and sometimes frequencies just above or below it are reflected by the ionized layers of the atmosphere and therefore known as sky wave propagation. Sky wave comes down to the earth due to reflection at some distant point will beyond horizon. Sky waves can reach the receiver on the opposite side of globe, when sky waves are reflected by ground and ionosphere several times. Waves are reflected back from the ionosphere which lies from 100-400 km above the earth's surface. This effect occurs in the MHz range (typically 10-30MHz or short wave)

Each of these modes of propagation has their own properties and frequency band requirements.

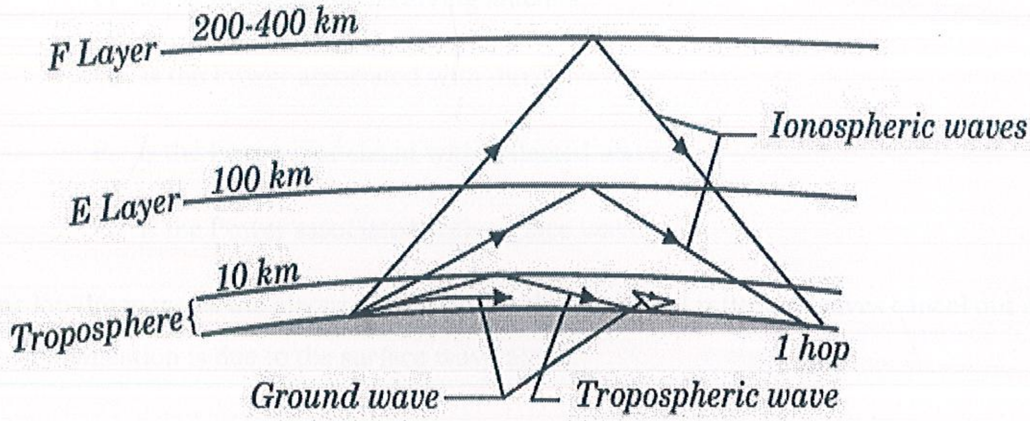

Fig 3.1 Radio wave propagation paths over the earth

3.2 Ground Wave Propagation

Ground wave propagation (or propagation close to the ground) consists of three modes of communication:

1. The direct path between the two antennas.

2. A reflection from the surface of the earth going from the transmitting antenna to the receiving antenna. And

3. Surface wave communication between the two.

The Power at the receiving antenna consists of the sum of three waves

(terms):

$$P_r = P_d + P_r + P_s$$

Where:

P_r is the Power at the receiving antenna;

P_d is the Power associated with direct wave;

P_r is the Power associated with reflected wave;

P_s is the Power associated with surface wave.

At low frequencies the electric fields due to the direct and reflected waves cancel out and communication is due to the surface wave alone.

3.3 Earth Reflection

The smooth finitely conducting earth the magnitude and phase of the reflected wave depend on following factors:-

(a) The roughness of the ground and

(b) ϵ_r, σ and ω (the frequency of operation) all taken together.

(c) The polarization of the wave: whether the **E** field is perpendicular or parallel to the plane of incidence.

When the earth is rough the reflected wave tends to scatter and may be much reduced in amplitude compared with smooth earth reflection.

To consider the roughness of the ground, there is a roughness factor R (also called the Raleigh roughness criterion) which is given by

$$R = 4\pi \sin\psi \left(\frac{\sigma}{\lambda}\right)$$

where R is the 'roughness' parameter

Ψ is the angle of incidence measured from the grazing angle

λ is the wavelength and

σ is the standard deviation of the surface irregularities.

For $R < 0.1$ we may assume the surface to be smooth, so we can consider the wave to be reflected in accordance with the laws of EM-waves,

While for $R > 10$ the surface may be considered rough, so we may treat the reflected wave to be absent or negligible.

A surface which might be considered rough for wave incident at high angles may approach being a smooth surface as the angle of incidence approaches grazing. It will be found that when the incident wave is near grazing over a smooth earth surface a reflection coefficient approaches -1.0 for both polarization i.e. vertical as well as horizontal polarization.

As we know earth is not the perfect dielectric .So its finite conductivity must be taken into account. The partially conducting dielectric can be considered as the dielectric that has complex dielectric constant i.e.

$$\varepsilon' = \varepsilon_r - j(\sigma/\omega)$$

3.3.1 Reflection Factor for Perpendicular Polarization:

The polarization which the electric vector is parallel to the boundary surface or perpendicular to the plane of incidence is known as Perpendicular or horizontal polarization. The reflection coefficient for the perpendicular polarization is given by

$$R_{\perp} = \frac{\cos\theta_i - \sqrt{(\varepsilon_2/\varepsilon_1) - \sin^2\theta_i}}{\cos\theta_i + \sqrt{(\varepsilon_2/\varepsilon_1) - \sin^2\theta_i}}$$

$$= \frac{\sin\psi - \sqrt{(\varepsilon_2/\varepsilon_1) - \cos^2\psi}}{\sin\psi + \sqrt{(\varepsilon_2/\varepsilon_1) - \cos^2\psi}}$$

Considering the term ϵ_2/ϵ_1 when medium 1 is air and medium 2 is the ground, then

$$\varepsilon_2 = \varepsilon_C = \varepsilon_0\varepsilon_r - j(\sigma/\omega)$$
$$\varepsilon_1 = \varepsilon_0$$

where ϵ_0, ϵ_r and σ are the permittivity of vacuum, the relative dielectric constant and conductivity of the ground respectively. so

$$\varepsilon' = \varepsilon_r - j(\sigma/\omega)$$

Therefore perpendicular polarization is given by-

$$R_{\perp} = \frac{\sin\psi - \sqrt{(\varepsilon_r - jx) - \cos^2\psi}}{\sin\psi + \sqrt{(\varepsilon_r - jx) - \cos^2\psi}}$$

3.3.2 Reflection Factor for Parallel Polarization:

The polarization in which magnetic vector is parallel to the boundary surface and the electric vector is parallel to the plane of incidence is known as parallel or vertical polarization. The reflection coefficient for the perpendicular polarization is given by

$$R_{\parallel} = \frac{(\varepsilon_2/\varepsilon_1)\cos\theta_i - \sqrt{(\varepsilon_2/\varepsilon_1) - \sin^2\theta_i}}{(\varepsilon_2/\varepsilon_1)\cos\theta_i + \sqrt{(\varepsilon_2/\varepsilon_1) - \sin^2\theta_i}}$$
$$= \frac{(\varepsilon_2/\varepsilon_1)\sin\psi - \sqrt{(\varepsilon_2/\varepsilon_1) - \cos^2\psi}}{(\varepsilon_2/\varepsilon_1)\sin\psi + \sqrt{(\varepsilon_2/\varepsilon_1) - \cos^2\psi}}$$
$$= \frac{(\varepsilon_r - jx)\sin\psi - \sqrt{(\varepsilon_r - jx) - \cos^2\psi}}{(\varepsilon_r - jx)\sin\psi + \sqrt{(\varepsilon_r - jx) - \cos^2\psi}}$$

where $x = \sigma/\omega\epsilon_0$ and where ϵ_0, ϵ_r and σ are the permittivity of vacuum, the relative dielectric constant and conductivity of the ground respectively.

3.4 The Surface Wave

Apart from the two modes of propagation (direct and reflected) we also have a third mode of propagation, namely the surface wave. In physics, a **surface wave** is a mechanical wave that propagates along the interface between differing media, usually two fluids with different densities.

A surface wave can also be an electromagnetic wave guided by a refractive index gradient. In radio transmission, surface wave is a part of ground wave that propagates close to the surface of the Earth.

The surface wave is guided by the ground which acts like a dielectric medium being diffracted over the surface of the earth, which acts as a boundary. These diffraction effects are greater as the radiation frequency go toward the lower frequencies (the kHz range and slightly higher). The surface wave is such that most of the energy of the wave is away from the ground.

3.4.1 The Surface Wave for the Vertical Dipole

For a vertical dipole the surface wave radiation field when $R >> \lambda$ is given by

$$\mathbf{E}_{su} = j30kIdl(1-R_{\|})F\left(\frac{e^{-jkR}}{R}\right)\left\{\mathbf{a}_k(1-u^2)\right.$$

$$\left.+\mathbf{a}_r\cos\psi'\left(1+\frac{\sin^2\psi'}{2}\right)u\sqrt{1-u^2\cos^2\psi'}\right\}$$

Where the following parameters are:

E_{su}:- the electric field of the surface wave at the receiving point

$$R_{\|} = \frac{(\varepsilon_r - jx)\sin\psi' - \sqrt{(\varepsilon_r - jx) - \cos^2\psi'}}{(\varepsilon_r - jx)\sin\psi' + \sqrt{(\varepsilon_r - jx) - \cos^2\psi'}}$$

which has already been introduced

$$u^2 = \frac{1}{(\varepsilon_r - jx)}$$

$$x = \frac{18\times 10^3\sigma}{f_{\text{MHz}}}$$

$$F = 1 - j\sqrt{\pi\omega}e^{-\omega}\operatorname{erfc}(j\sqrt{\omega})$$

$$\omega = -jkR\frac{u^2(1-u^2\cos^2\psi')}{2}\left[1+\frac{\sin\psi'}{u\sqrt{1-u^2\cos^2\psi'}}\right]^2$$

$$\operatorname{erfc}(j\omega) = \frac{2}{\sqrt{\omega}}\int_{j\omega}^{\infty} e^{-v^2}dv$$

The function F introduces attenuation that is dependent upon distance, frequency and on the constant of the earth along which wave is travelling. For distances within a few wavelengths of the dipole F has a value of very nearly unity and it approaches unity as distance R approaches zero. It is called as unattenuated surface wave.

For lower frequencies and good ground conductivities attenuated surface wave is very small except for angles near grazing. At the same angle, the space wave is always zero because the direct and the ground reflected waves cancel.

For higher frequencies and poor conductivities the unattenuated surface wave still has a value of 2 but it also has appreciable value at high angles. However this wave attenuates very rapidly with distance because of factor F.

We can see from the formulae that the factor F is of great complexity and decays rapidly with increasing value of kR.We also take a look at the surface wave as $\psi = 0$ which is the case for long distance communication. Then

$$\omega_{\psi'=0} = p_1 = -jkR\frac{u^2(1-u^2)}{2} = -\frac{jkR}{2}\left\{\frac{1}{\varepsilon_r - jx}\left(1-\frac{1}{\varepsilon_r - jx}\right)\right\}$$

$$= -j\left(\frac{R}{\lambda}\right)\underbrace{\left\{\frac{\pi}{\varepsilon_r - jx}\left(1-\frac{1}{\varepsilon_r - jx}\right)\right\}}_{\text{The factor a}}$$

$$= pe^{jb}$$

where p is known as the *numerical distance* and b is the *phase constant* and both are real and greater than zero. The factor

$$a = \frac{\pi}{\varepsilon_r - jx}\left(1-\frac{1}{\varepsilon_r - jx}\right)$$

$$p = \frac{R}{\lambda}|a|$$

$$b \cong \tan^{-1}\left(\frac{\varepsilon_r + 1}{x}\right)$$

is the complex part.

If we consider the function $F_{\psi'=0}$ then

$$A = |F_{\psi'=0}| = \left|1 - j\sqrt{\pi p_1}e^{-p_1}\operatorname{erfc}(j\sqrt{p_1})\right|$$

where A is called the ground-wave attenuation factor. The numerical distance p depends upon the frequency and the ground constant as well as upon the actual distance to the transmitter. It is proportional to the distance and to the square of frequencies and varies almost inversely with the ground conductivity. The phase constant b is measure of the power factor angle of the earth. Since in the calculation of the power carried by the surface only a good approximation is the requirement,

$$A \approxeq A_1 - \sin(b)\sqrt{\frac{p}{2}}e^{-(5/8)p}$$

Where

$$A_1 = \frac{2+0.3p}{2+p+0.6p^2}$$

The function is almost equal to 1 (no attenuation) for the range $0 < p < 0.1$.

A lies in the range $0.1 < A < 1$ for $0.1 < p < 10$ for various values of b; and for greater values of p, A decreases linearly on the logarithmic scale. In the last range

$$A \approxeq \frac{1}{2p-3.7}$$

This relation shows that at large numerical distances A is inversely proportional to p. This means that at large numerical distances the surface wave will vary inversely as the square of distance from the transmitter.

3.4.2 Surface Wave for a Horizontal Dipole

The surface wave for a horizontal dipole on the surface of the earth is given by

$$E_{su} = j30kIdlF\left(\frac{e^{-jkR}}{R}\right)\left\{\left[(1-R_{\|})Fu\cos\phi\sqrt{1-u^2\cos^2\psi'}\right]\times\right.$$

$$\left[\cos\psi'\left(1+\frac{\sin^2\psi'}{2}\right)a_k + u\sqrt{1-u^2\cos^2\psi'}\left(\frac{1-\sin^4\psi' - \frac{(1-R_\perp)G}{(1-R_{\|})u^2F)}}{1-u^2\cos^2\psi'}\right)a_\rho\right]$$

$$\left. + \sin\phi(1-R_\perp)Ga_\phi\right\}$$

Where

$$G = \left[1 - j\sqrt{\pi v}e^{-v}\mathrm{erfc}(j\sqrt{v})\right]$$

$$v = -\frac{jkR(1-u^2\cos^2\psi')}{2u^2}\left(1+\frac{u\sin\psi'}{\sqrt{1-u^2\cos^2\psi'}}\right)^2$$

The function G is an attenuation function for horizontal polarization. At large numerical distances G approaches u^4F, which is always much less than unity.

It is evident that the horizontal polarized surface wave will be attenuated more rapidly than vertical polarized wave of same frequency.

From these expressions, it is clear that for $\psi' = 0$ the electric field become

$$E_{su} = j30kIdlF\left(\frac{e^{-jkR}}{R}\right)\left\{\left[(1-R_{\|})Fu\cos\phi\sqrt{1-u^2}\right]\times\right.$$

$$\left.\left[a_k + u\left(\frac{1-\frac{(1-R_\perp)G}{(1-R_{\|})u^2F)}}{\sqrt{1-u^2}}\right)a_\rho\right] + \sin\phi(1-R_\perp)Ga_\phi\right\}$$

$$G = \left[1 - j\sqrt{\pi v}e^{-v}\mathrm{erfc}(j\sqrt{v})\right]$$

$$v = -\frac{jkR(1-u^2)}{2u^2}$$

By observing these equations, we notice that in the direction $\Phi = 0$ both components the $\mathbf{a}_k$(vertically polarized) and $\mathbf{a}_p$ (horizontally polarized) are present. In the direction $\Phi = 90^0$ only the horizontally polarized component is present.

To compute the attenuation at a distance *R* from the source, the same factor *A* of Equation is used with

$$p = \frac{\pi R}{\lambda}\frac{x}{\cos b'}$$
$$b = 180° - b'$$
$$b' = \tan^{-1}\frac{\varepsilon_r - 1}{x}$$

and $x = 18{\times}10^3\ \sigma / f_{MHz}$. Computations and experimental results show that the surface wave contributes very slightly to communication using horizontally placed dipoles.

For a given actual distance R, the numerical distance p will be greater for horizontal polarization than for vertical polarization. This means greater attenuation for the horizontal polarized wave than for the vertical polarization. At low and medium frequencies, where x is large, the difference in attenuation is great and only vertical polarized waves need to be considered. In this frequency range the antennas used will be designed to radiate and receive vertically polarized polarized signals. At high and very high frequencies the attenuation of the surface wave is very large with the result that the surface wave propogation is limited to very short distances.

3.5 Approximations for VHF Propagation

Consider two vertical dipole antennas elevated above the surface of the earth at heights of h_1 and h_2 the *frequency which is used is in the high and very high frequency range* (HF and VHF). Then the vertical component of the electric field at the receiving antenna is

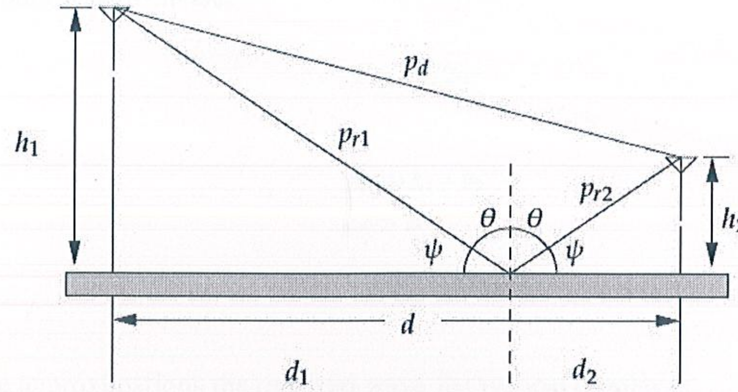

Fig 3.2 Figure Of VHF Propagation

$$E_z = j30kIdl\left\{\cos^2\psi\left[\boxed{\frac{e^{-jkR_1}}{R_1} + R_{\|}\frac{e^{-jkR_2}}{R_2}} + \boxed{(1-R_{\|})F\frac{e^{-jkR_2}}{R_2}}\right]\right\}$$

where the first boxed term is the space wave, and the second one is the surface wave. Here $R_1 = p_d$ and $R_2 = p_{r1} + p_{r2}$ of the figure. This expression is accurate for distances from the antenna larger than a few wavelengths.

However since we need to make an approximate computation, we make the following approximations:

1) The surface wave can be neglected in comparison with the space wave.
2) The angle ψ is very small so that the reflecting factor R_v

Or

$R_h = -1$

For large numerical distances

$$F \approx -1/2\omega$$

$$ud \gg h_1 + h_2$$
$$|\omega| > 20$$

With these approximations the received wave for vertical dipoles is

$$E_z = \frac{j30kIdl}{d}\left\{e^{-jkR_1} + R_{\|}e^{-jkR_2} - (1 - R_{\|})\frac{e^{-jkR_2}}{2\omega}\right\}$$

For small values of Ψ

$$R_{\|} \cong -1 + 2\frac{j(jx - \varepsilon_r)\,\psi}{\sqrt{jx - \varepsilon_r + 1}}$$

Also

$$R_1 = \sqrt{d^2 + (h_1 - h_2)^2} \cong d\left[1 + \frac{(h_1 - h_2)^2}{2d^2}\right]$$
$$R_2 = \sqrt{d^2 + (h_1 + h_2)^2} \cong d\left[1 + \frac{(h_1 + h_2)^2}{2d^2}\right]$$
$$R_2 - R_1 \cong \frac{(h_1 + h_2)^2}{2d} - \frac{(h_1 - h_2)^2}{2d} = \frac{2h_1h_2}{d}$$

R_2 - R_1 obtained by using the first two terms of series will give more accurate numerical answer than the exact computation using a reasonable number of significant figures.

This is because when two large and nearly equal numbers are subtracted one from the other significant figures are lost so that it is necessary to start with very large number of significant figures in order to end up with only the fair accuracy.

In the approximate method one works directly on the difference between the numbers and no significant figures are lost.

So Equation becomes

$$E_z = \frac{j30kIdle^{-jkR_1}}{d}\left\{1 + R_{\|}e^{-jk(R_2-R_1)} - (1-R_{\|})\frac{e^{-jk(R_2-R_1)}}{2\omega}\right\}$$

$$= \frac{j30kIdle^{-jkR_1}}{d}\left\{1 + \underbrace{R_{\|}}_{\cong -1} e^{-jk(2h_1h_2/d)} - \underbrace{(1-R_{\|})\frac{e^{-jk(2h_1h_2/d)}}{2\omega}}_{\text{neglected}}\right\}$$

We now use the following approximations:

$$R_{\|} \cong -1$$

$$e^{-jk(2h_1h_2/d)} = \cos(2kh_1h_2/d) - j\sin(2kh_1h_2/d)$$

$$\cong 1 - j\frac{2kh_1h_2}{d}$$

which gives

$$\boxed{|E_z| \cong \frac{60k^2Il_{eff}h_1h_2}{d^2}}$$

The received field strength is proportional to the height of transmitting antenna, the height of receiving antenna, and inversely proportional to square of the distance between them.

Chapter 4

PROBLEM ANALYSIS

4.1 Aim of Project

Through this project we are developing an antenna design which will give a precision guidance to aircraft at the time of landing and Further we are trying to keep the power same throughout its glide path so that there is a equal distribution of power all over the path.

Basically we are working with antenna array so that the desired overall radiation pattern could be obtained when several antenna elements are combined to form an array of antennas.

We know as the distance increase, the power also increases so when the aircraft is at a far distance from the runway it receives less power as compared to the case when the aircraft is nearer due to which enough power get wasted.

To overcome that we are designing an antenna array which will radiate the desired pattern for landing and will provide same amount of power during the glide path irrespective of the distance.

4.2 Resources

MATLAB

MATLAB is a high-level language and interactive environment that enables you to perform computationally intensive tasks faster than with traditional programming languages such as C, C++, and Fortran.

Key Features:

* High-level language for technical computing
* Development environment for managing code, files, and data
* Interactive tools for iterative exploration, design, and problem solving
* Mathematical functions for linear algebra, statistics, Fourier analysis, filtering, optimization, and numerical integration
* 2-D and 3-D graphics functions for visualizing data
* Tools for building custom graphical user interfaces
* Functions for integrating MATLAB based algorithms with external applications and languages, such as C, C++, Fortran, Java, COM, and Microsoft Excel.

4.3 Implementations

4.3.1 Figure representing project

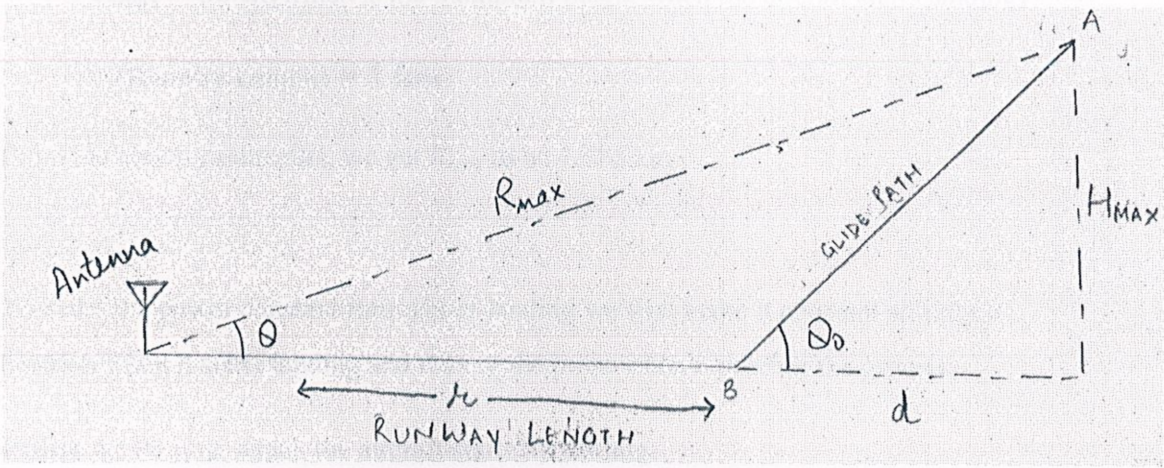

Fig 4.1 Project Figure

4.3.2 Power receiving through Direct Wave(LOS)

Concentrating on our basic idea of distributing same amount of power throughout the glide path irrespective of the distance we take a generalized equation of power i.e.

$$P(\Theta) = P_0/R^2 + P_1\,\Theta/R^2$$

Now considering the terms mention in the above figure

$$H_{max} = d*\tan(\Theta_0) \qquad R_{max} = \sqrt{H_{max}^2 + (r+d)^2}$$

$$R_{max} = \sqrt{H_{max}^2 + (r + H_{max}\,*\cot\Theta_0)^2}$$

Taking $\Theta_0 = 5^0$ $\qquad$ $\sin(\Theta) = H_{max} / R_{max}$

H_{max} = 60 m(which is the maximum height when the aircraft starts landing**)**

r (Runway Length**) = 1 km**

From the above parameters, we get R_{max} to be 1.686 km

To make the power constant throughout landing we first make it constant at highest position when it starts landing and then at the point when it touches the ground.

Point A: Point at which the aircraft starts its landing.

$$P(\Theta) = P_0/R_{max}^2 + P_1\,\Theta/R_{max}^2 = C(1\text{ Watt})$$

$$R_{max} = 1.686\text{ km} \qquad \Theta = 2.04$$

$$P_0 + P_1(2.04) = 2.482 \qquad \text{....(1)}$$

Point B: Point at which aircraft lands successfully.

$$P(\Theta) = P_0/R^2 + P_1\,\Theta/R^2 = C(1\text{ Watt})$$

r = 1 km (i.e. Runway length**)**

Θ = 0(as the aircraft is now on earth**)**

$$P_o = 1 \qquad ....(2)$$

Solving for P_o and P_1 from equation (1) and (2)

we get $\qquad P_o = 1 \qquad P_1 = 0.903$

So Power Equation now becomes

$$P(\Theta) = 1/R^2 + 0.903/R^2 = C(1\text{ Watt})$$

From this equation we find power at various possible distance r, at various heights of aircraft and also at different angle Θ and further check the Associated error percentage in the Results

Height(km)	Θ(Degrees)	R(km)	Power (Watts/km^2)	Error(%)
0.06	2.04	1.686	1	0
0.05	1.82	1.572	1.069	6.9
0.04	1.57	1.467	1.138	13.8
0.03	1.28	1.343	1.195	19.5
0.02	0.93	1.228	1.22	22
0.01	0.51	1.114	1.171	17.1
0.005	0.27	1.057	1.113	11.3
0.002	0.11	1.022	1.0525	5.25
0	0	1	1	0

Table 4.1 Corresponding Power and Error Percentage Table

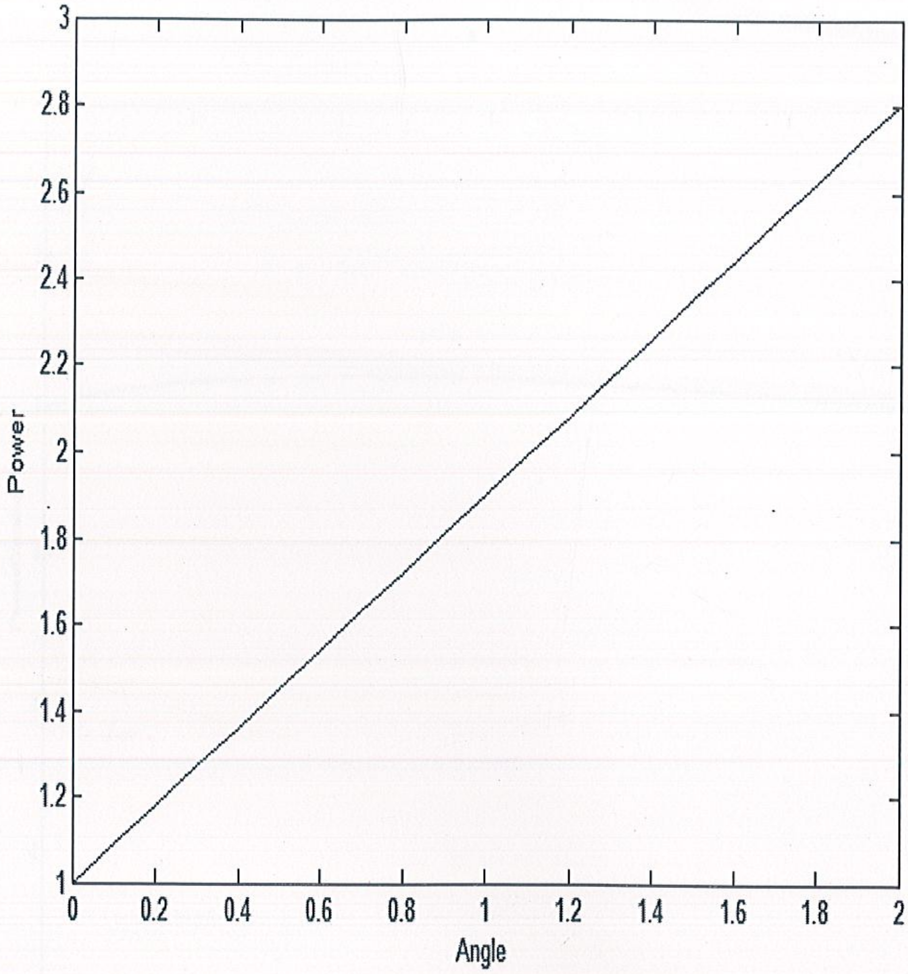

Fig 4.2 Direct wave Graph Of Power(P(Θ)) Vs Angle(Θ)

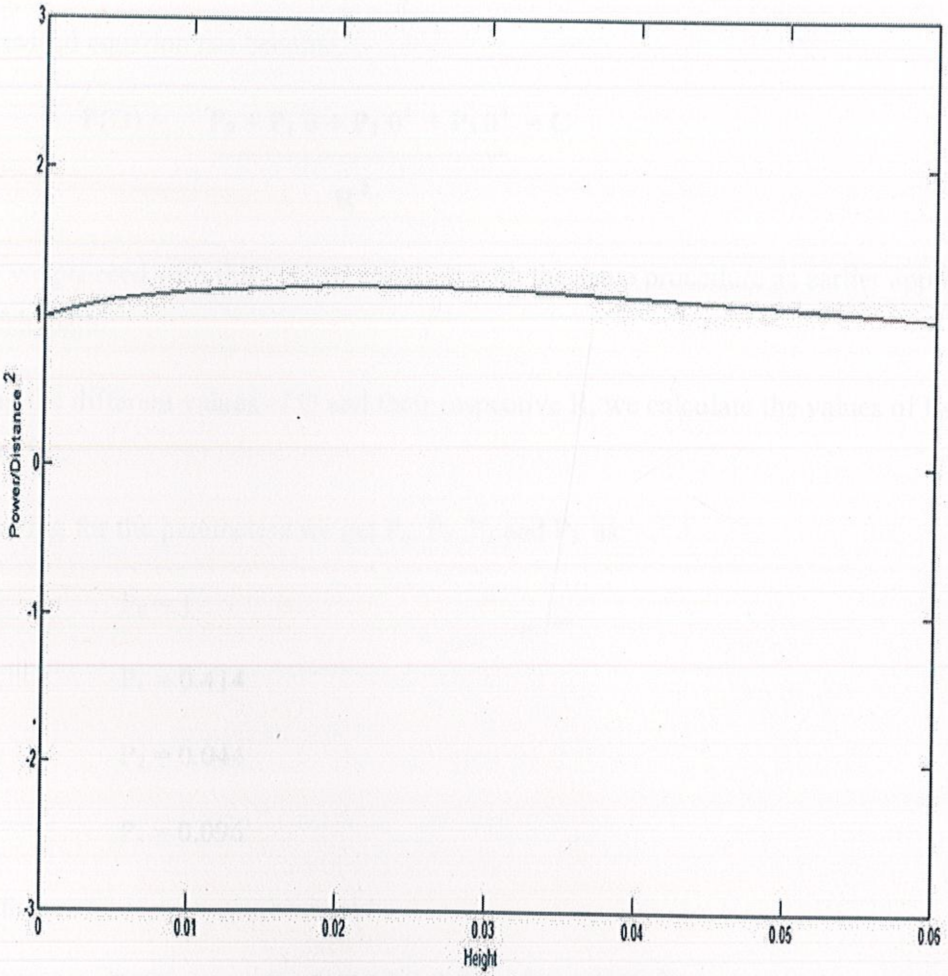

Fig 4.3 Direct Wave Graph of power/distance^2 Vs Height

As we have seen in the result table that the maximum associated error percentage is considerably high that is up to 22%.

So With the idea to minimize the error as much as we can, we expand the equation by taking the function Θ up till Θ^3.

The revised equation has become:

$$\mathbf{P(\Theta) = \frac{P_0 + P_1\,\theta + P_2\,\theta^2 + P_3\,\theta^3}{R^2} = C}$$

Now we proceed with this revised equation with the same procedure as earlier applied on the glide path.

Taking the different values of Θ and their respective R, we calculate the values of P_0, P_1 ,P_2 and P_3 .

On solving for the parameters we get P_0, P_1 ,P_2 and P_3 as:

$P_0 = 1$

$P_1 = 0.414$

$P_2 = 0.044$

$P_3 = 0.096$

Therefore,

$$\mathbf{P(\Theta) = \frac{1 + 0.414\,\theta + 0.044\,\theta^2 + 0.096\,\theta^3}{R^2}}$$

Again with this equation we find power at various possible distance r, at various heights of aircraft and at different angle Θ and further check the Associated error percentage in our Results

Height(m)	Θ(Degrees)	R(Kms)	Power(Watts)	Error(%)
0.06	2.04	1.686	1	0
0.05	1.82	1.572	1.007	0.7
0.04	1.57	1.457	1.002	0.2
0.03	1.28	1.343	1	0
0.02	0.93	1.228	0.994	0.6
0.01	0.51	1.114	0.995	0.5
0.005	0.27	1.057	1	0
0.002	0.11	1.022	1.0016	.16
0	0	1	1	0

Table 4.2 Corresponding Power and Error Percentage Table

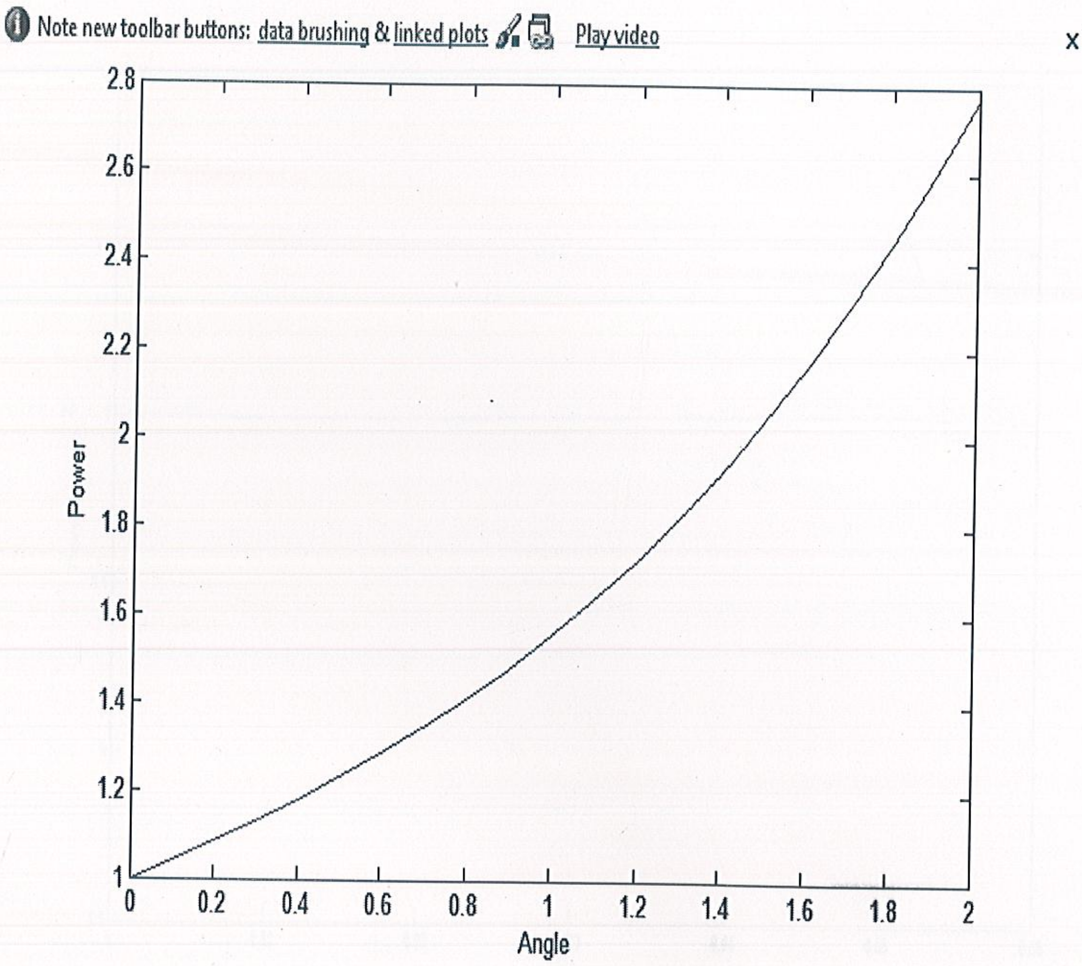

Fig 4.4 Direct Wave Graph Of Revised Power(P(Θ)) Vs Angle(Θ)

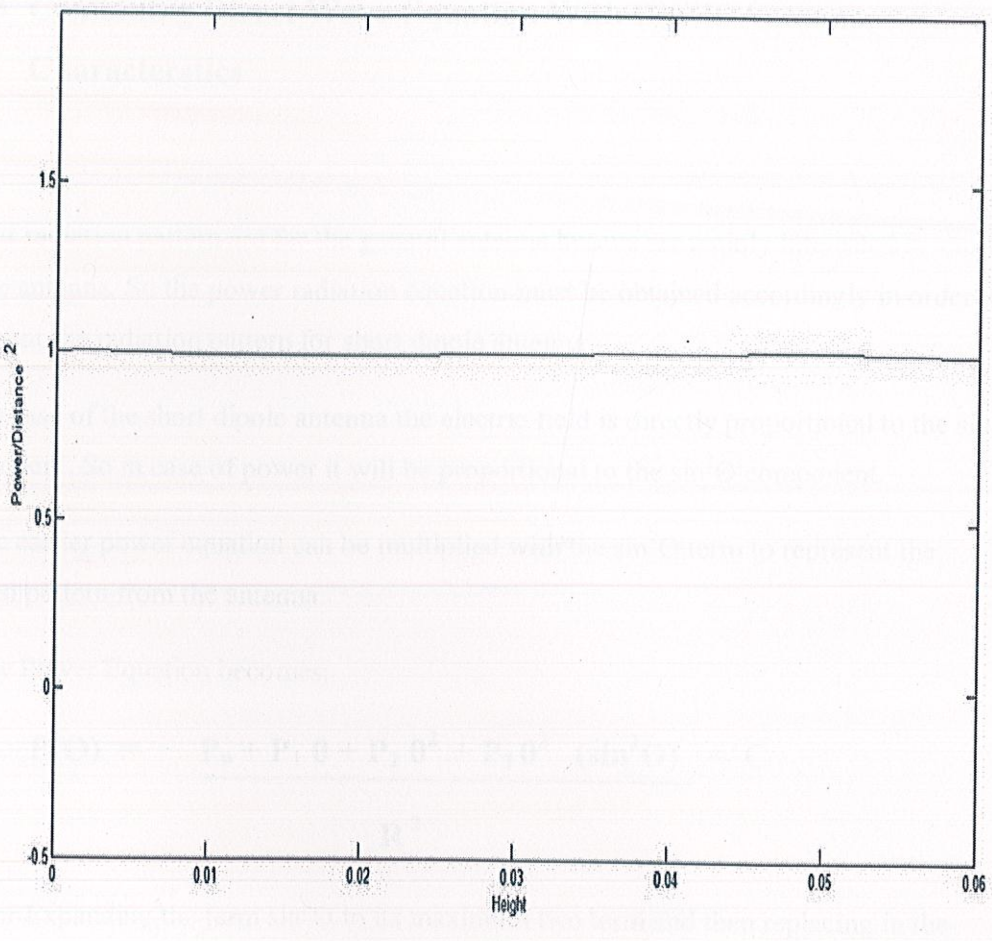

Fig 4.5 Direct Wave Graph Of Revised power/distance^2 Vs Height

We have seen in the last result table that the maximum associated error percentage has been reduced up to 0.7% which is much less than what we have seen in our earlier results. So, working with this revised equation makes our result more précised than the earlier one.

4.3.3 Combining Direct Wave Equation With Dipole Antenna Characterstics

Earlier radiation pattern are for the general antenna but we are mainly interested in short dipole antenna. So the power radiation equation must be obtained accordingly in order to represent the radiation pattern for short dipole antenna

In the case of the short dipole antenna the electric field is directly proportional to the sinΘ component. So in case of power it will be proportional to the $\sin^2\Theta$ component.

So the earlier power equation can be multiplied with the $\sin^2\Theta$ term to represent the desired pattern from the antenna.

Now Power Equation becomes:

$$P(\Theta) = \frac{P_0 + P_1\,\theta + P_2\,\theta^2 + P_3\,\theta^3 \;\; (\sin^2\Theta)}{R^2} = C$$

Further Expanding the term $\sin^2\Theta$ to its maximum two term and then replacing in the above equation we get:

$$P(\Theta) = \frac{(P_0 + P_1\,\theta + P_2\,\theta^2 + P_3\,\theta^3)\;(\theta^2 + (\theta^6)/36 - (\theta^4)/3)}{R^2} = C$$

Proceeding with the same procedure of finding the constants keeping in mind to make power constant irrespective of distance, we calculate the values of P_0, P_1 ,P_2 and P_3 .

With above equation we find power at various possible distance R, at various heights of aircraft and at different angle Θ and plot the graph between angle and power

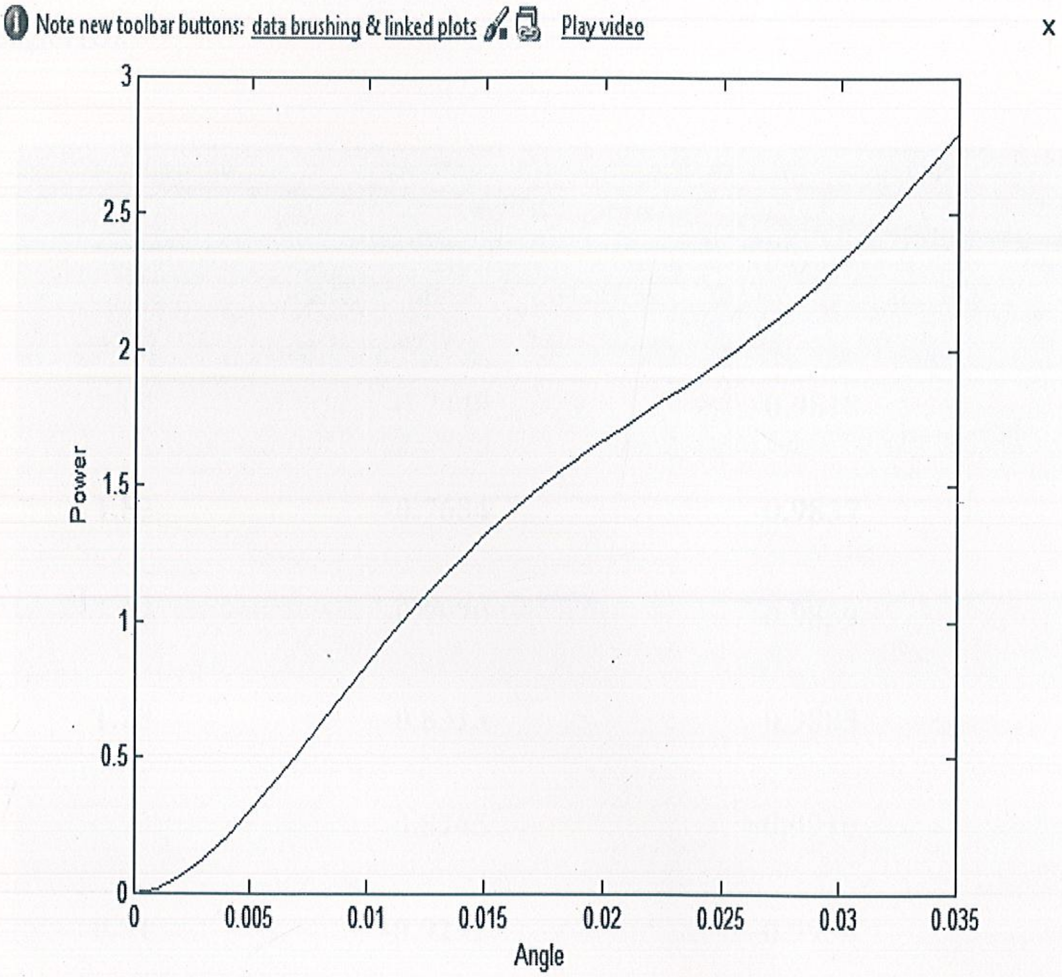

Fig 4.6 Direct Wave Graph Of Revised Power(P(Θ)) Vs Angle(Θ)

4.3.4 Vertical Polarization

So for calculating vertical polarization we will have to find the frequency which are not being used so that we can make our project feasible.

Therefore we found some frequency from which we took 40 MHz at which we calculate the reflection factor for vertical polarization and for horizontal polarizations at different angles (Θ).

Θ(Degrees) At 40 Mhz	Rv(Reflection Factor for Vertical Polarization)	Rh(Reflection Factor for Horizontal Polarization)
2.04	-0.7440	-0.9818
1.82	-0.7684	-0.9837
1.57	-0.7970	-0.9859
1.28	-0.8313	-0.9885
0.93	-0.8745	-0.9916
0.51	-0.9292	-0.9954
0.27	-0.9619	-0.9976
0.11	-0.9843	-0.9990

Table 4.3 Corresponding Table For Reflection Factor

4.3.5 VHF Propagation

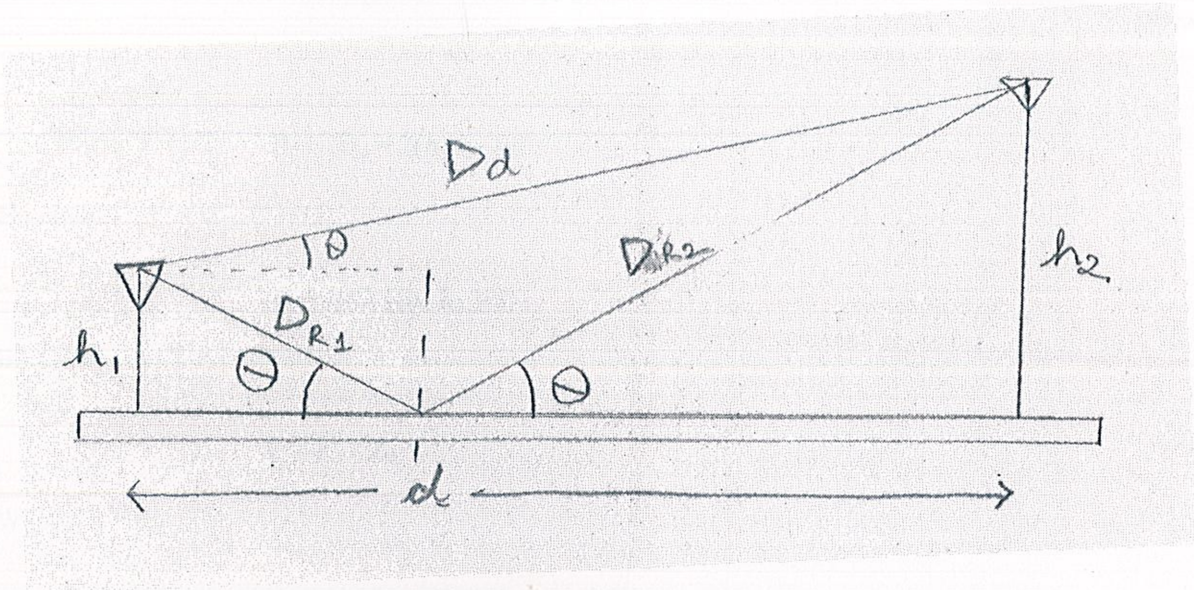

Fig 4.7 Figure for VHF Propagation

The Electric field at the receiving antenna due to a current I ampere in a transmitting antenna is given by

$$\mathbf{E = 60I/d\ (I1 - R_v\,(Cos(\alpha) + jSin(\alpha))I)}$$

where α is the difference in path length between direct and reflected waves expressed in degrees.

i.e. $$\alpha = 2\pi/\lambda\ (D_r - D_d)$$

D_r (Reflected wave distance) = $d \sqrt{\ 1 + ((h_1 + h_2)/d)^2}$

D_d (Direct wave distance) $= \mathbf{d \sqrt{1 + ((h_1 - h_2)/d)^2}}$

Using the binomial expansion when x << 1,

$$\mathbf{(1+x)^{1/2} = 1 + \tfrac{1}{2} x}$$

Then

$$\mathbf{D_r - D_d = 2(h_1 h_2)/d}$$

So now

$$\boldsymbol{\alpha = 4\pi/\lambda ((h_1 h_2)/d)}$$

Power becomes

$$\mathbf{P = E^2 / Z_0}$$

Where

Z_0 (Characterstic impedance)= 377 ohm

With these formulae we calculate the power at different heights which is the resultant of both direct wave and ground reflected wave power

h_2 (m)	d(m)	θ(degree)	α	R_v	P(μW)
60	1785.8	2.04	16.127	-0.7440	0.3716
50	1671.5	1.82	14.358	-0.7684	0.3045
40	1557.2	1.57	12.33	-0.7970	0.2335
30	1442.9	1.28	9.790	-0.8313	0.1606
20	1328.6	0.93	7.225	-0.8745	0.0887
10	1214.3	0.51	3.593	-0.9292	0.0259
5	1157.2	0.27	2.073	-0.9619	0.0081
2	1122.9	0.11	0.855	-0.9843	0.0014

Table 4.4 Corresponding Table for VHF Propagation

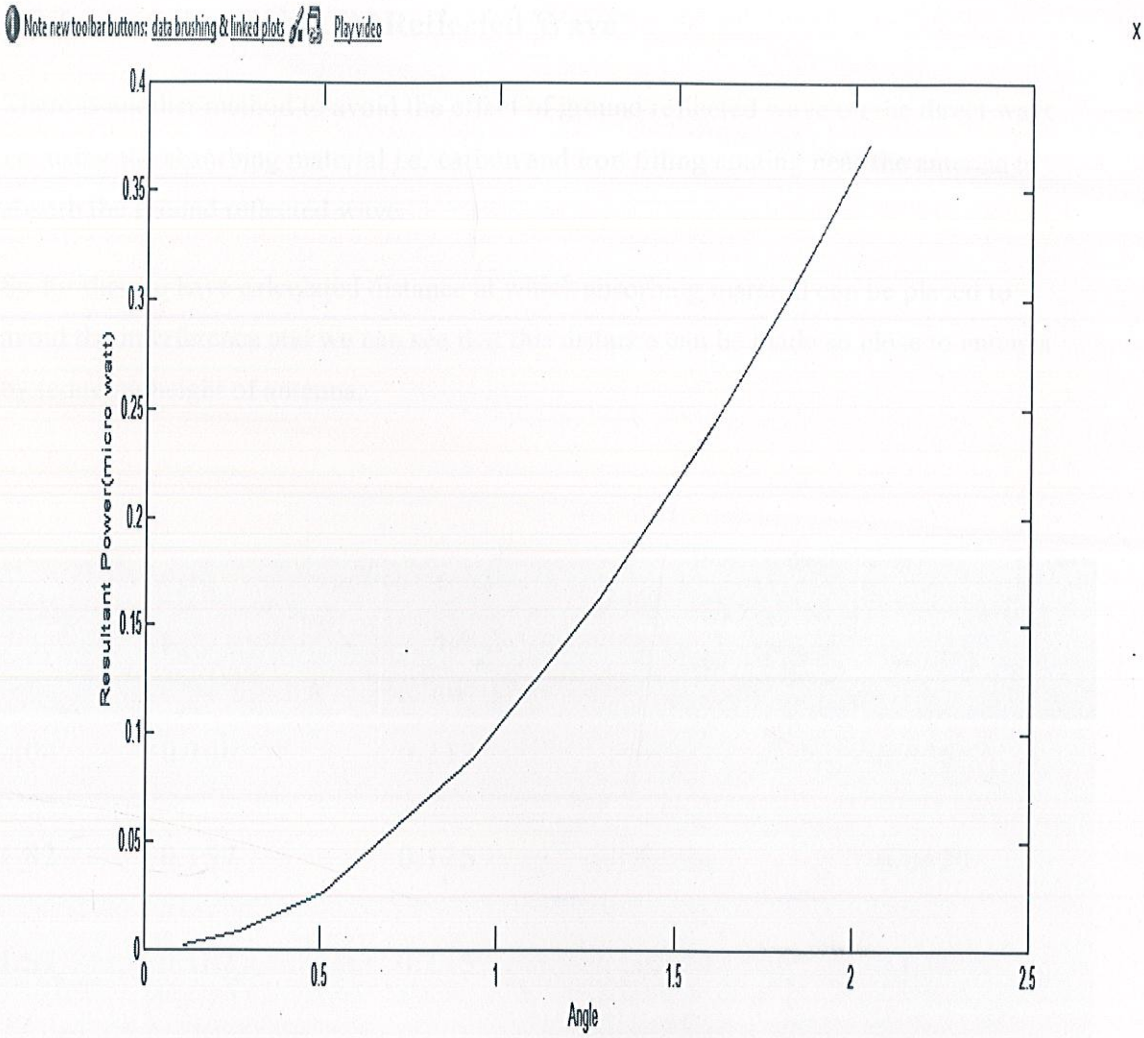

Fig 4.8 VHF Propagation Graph for Power Vs Angle

4.3.6 Avoiding Effect Of Reflected Wave

There is another method to avoid the effect of ground reflected wave on the direct wave i.e. using the absorbing material i.e. carbon and iron filling coating near the antenna to absorb the ground reflected wave.

So for this we have calculated distance at which absorbing material can be placed to avoid the interference and we can see that this distance can be made so close to antenna by reducing height of antenna.

Θ(Degrees)	DB(h1=0.005 kms)	DB(h1=0.004 kms)	DB(h1=0.003 kms)	DB(h1=0.002 kms)
2.04	0.140	0.112	0.084	0.056
1.82	0.157	0.125	0.094	0.0629
1.57	0.182	0.145	0.109	0.072
1.28	0.22	0.179	0.134	0.089
0.93	0.308	0.246	0.184	0.123
0.51	0.56	0.449	0.337	0.224

Table 4.5 Corresponding Table Of Distances to Avoid Reflected Wave

4.3.6 Surface Wave

The electric field for the surface wave reduces to

$$E_{su} = \frac{60I^{*}|(1-R_{||})|}{R^{*}\ \ 2p}$$

Where

$$p = R \cos(b)/ \lambda\ x$$

$$b = \tan^{-1}(\epsilon_r + 1)/x$$

$$x = \sigma/\omega\epsilon_v$$

$$= 18 * 10^3\ \sigma/f_{Mhz}$$

Power becomes

$$P = E^2 / Z_0$$

where

Z_0 (Characterstic impedance)= 377 ohm

$R_{\|}$	R(km)	b	p	E_{su}	Power(10^{-8})
-0.7440	1.686	71.35	41.8015	0.000742	0.146
-0.7684	1.572	71.35	38.9751	0.0008659	0.198
-0.7970	1.457	71.35	36.123	0.001	0.278
0.8313	1.343	71.35	33.2974	0.0012	0.4003
-0.8745	1.228	71.35	30.4962	0.0015	0.6
-0.9292	1.114	71.35	27.6197	0.0019	0.938
-0.9619	1.057	71.35	26.2065	0.0021	1.197
-0.9843	1.022	71.35	25.338	0.0023	1.4017

Table 4.6 Corresponding Table For Power Received By Surface Wave

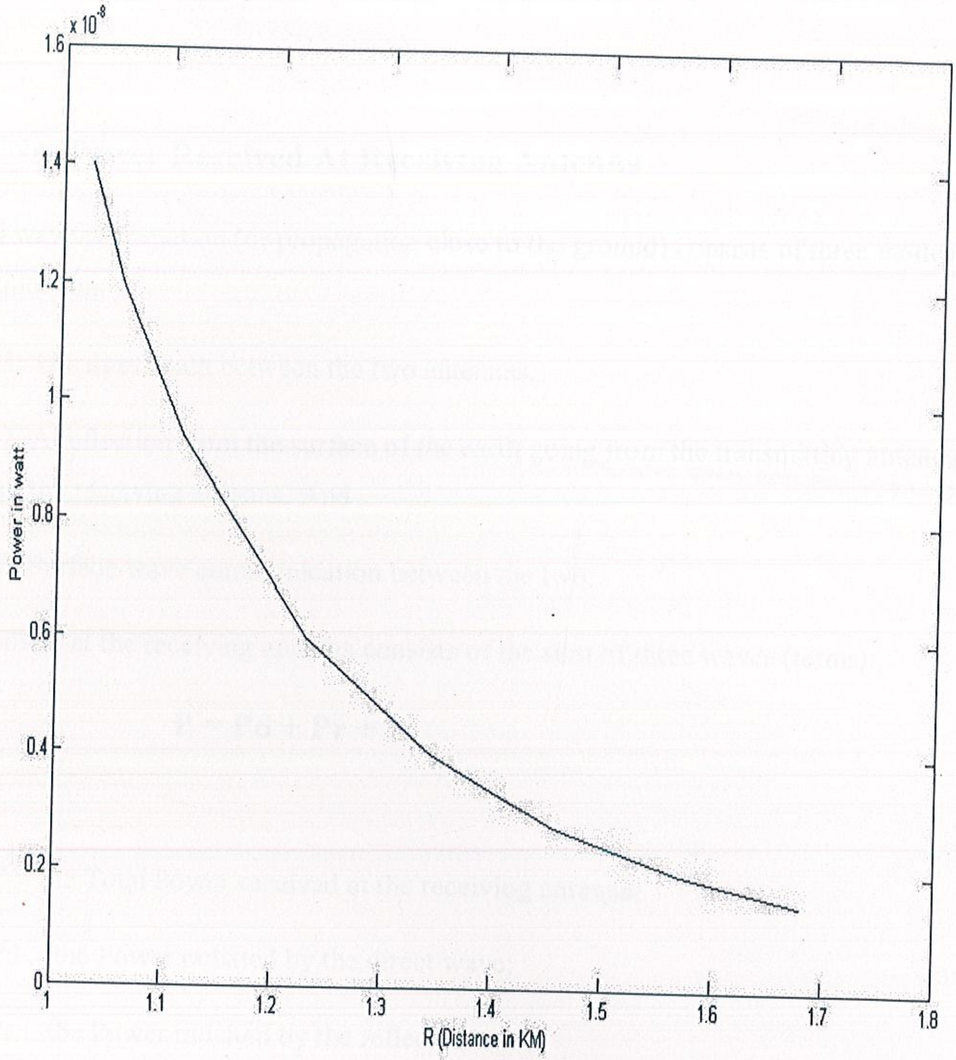

Fig 4.9 Graph of Power received by surface wave vs R(km)

4.4 Final Results

4.4.1 Net Power Received At Receiving Antenna

Ground wave propagation (or propagation close to the ground) consists of three modes of communication:

1. The direct path between the two antennas.

2. A reflection from the surface of the earth going from the transmitting antenna to the receiving antenna. And

3. Surface wave communication between the two.

So the power at the receiving antenna consists of the sum of three waves (terms):

$$\mathbf{P = Pd + Pr + Ps}$$

Where

P :- the Total Power received at the receiving antenna;

Pd :- the Power radiated by the direct wave;

Pr :- the Power radiated by the reflected wave;

Ps :- the Power radiated by the surface wave.

Θ(Degrees)	R(KM)	Pd(10^4w)	Pr(μw)	Ps(μw)	P(10^{-4} w)
2.04	1.686	2.8427	0.3716	0.146	3.21576
1.82	1.572	2.478	0.3045	0.198	2.78448
1.56	1.457	2.1299	0.2335	0.278	2.36618
1.28	1.343	1.8033	0.1606	0.4003	1.9679
0.93	1.228	1.5003	0.0887	0.6	1.595
0.51	1.114	1.2353	0.0259	0.938	1.2702
0.27	1.057	1.1169	0.0081	1.197	1.13697
0.11	1.027	1.0462	0.0041	1.4017	1.064

Table 4.7 Corresponding table Of Net Power Received At Receiving Antenna

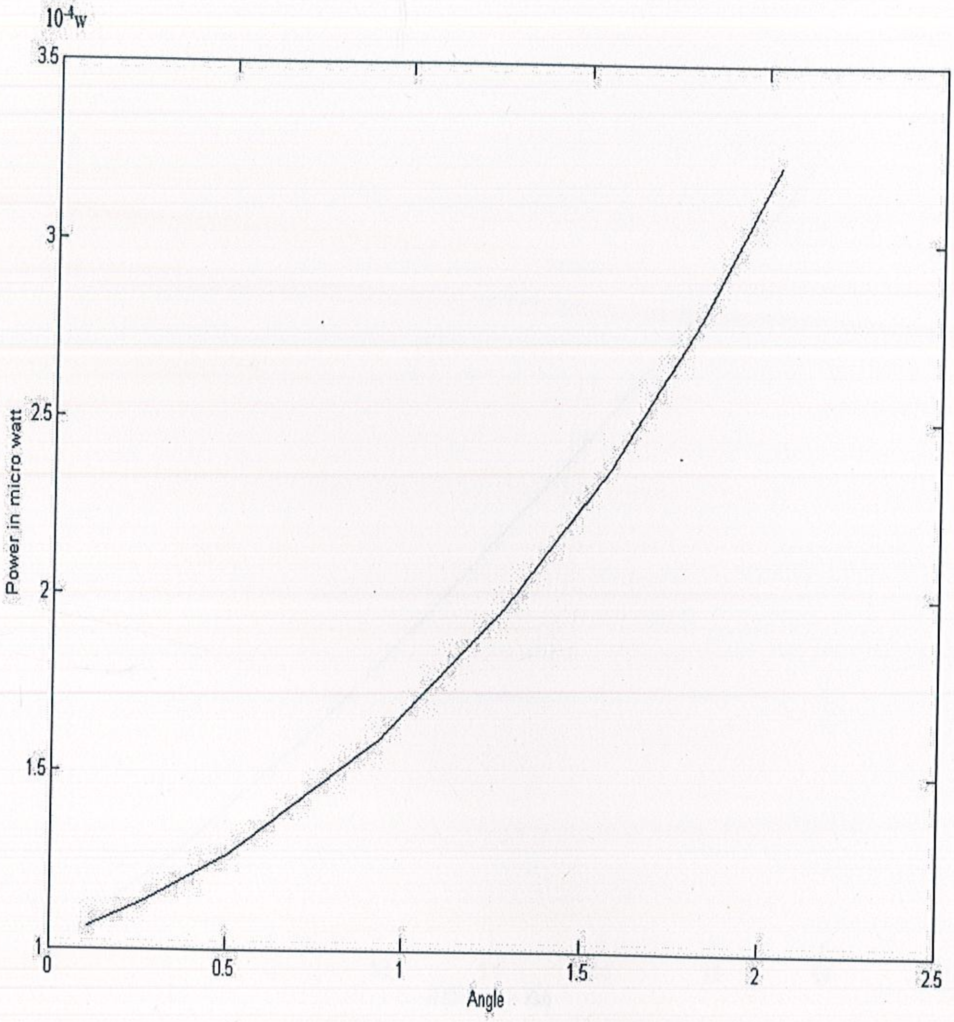

Fig 4.10 Graph Of Net Power received vs Angle

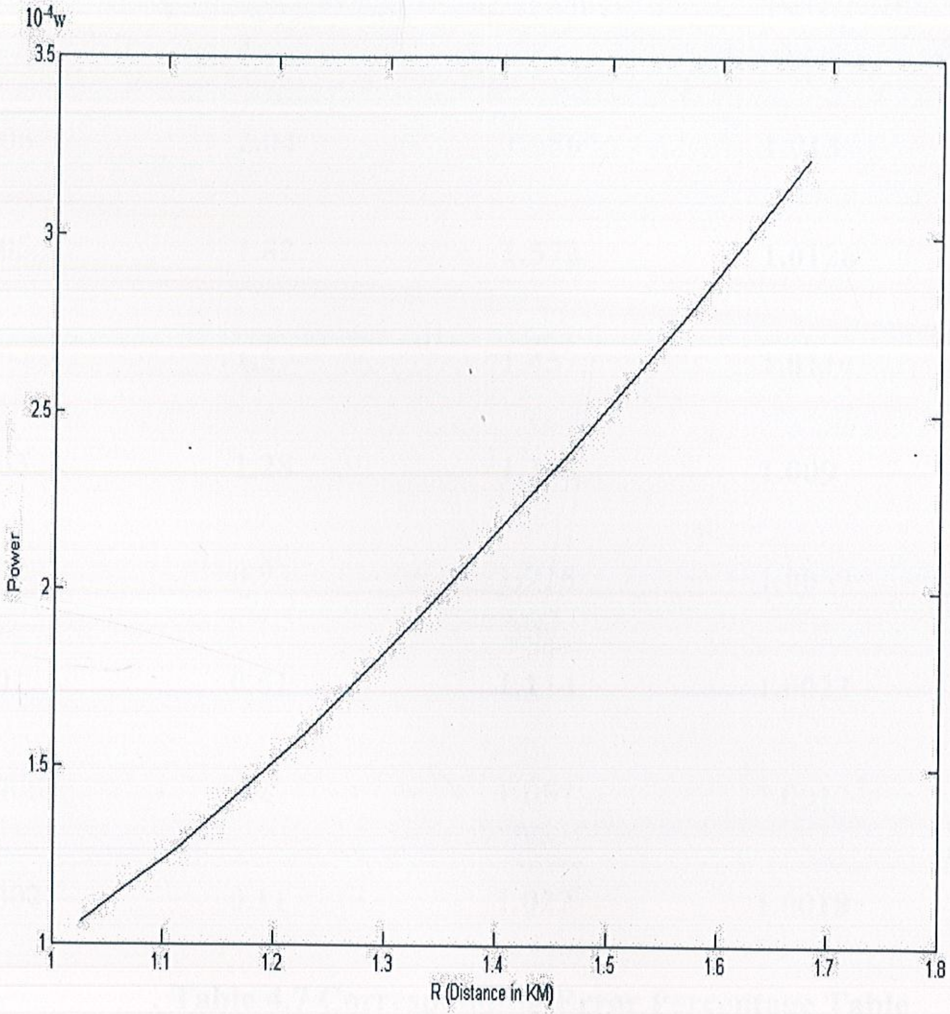

Fig 4.11 Graph of Net Power Received vs R(Distance from antenna to aircraft)

Height(m)	Θ(Degrees)	R(Kms)	Power/R*R(Watts)
0.06	2.04	1.686	1.013
0.05	1.82	1.572	1.0126
0.04	1.57	1.457	1.0114
0.03	1.28	1.343	1.009
0.02	0.93	1.228	1.0057
0.01	0.51	1.114	1.0023
0.005	0.27	1.057	1.0017
0.002	0.11	1.022	1.0018

Table 4.7 Corresponding Error Percentage Table

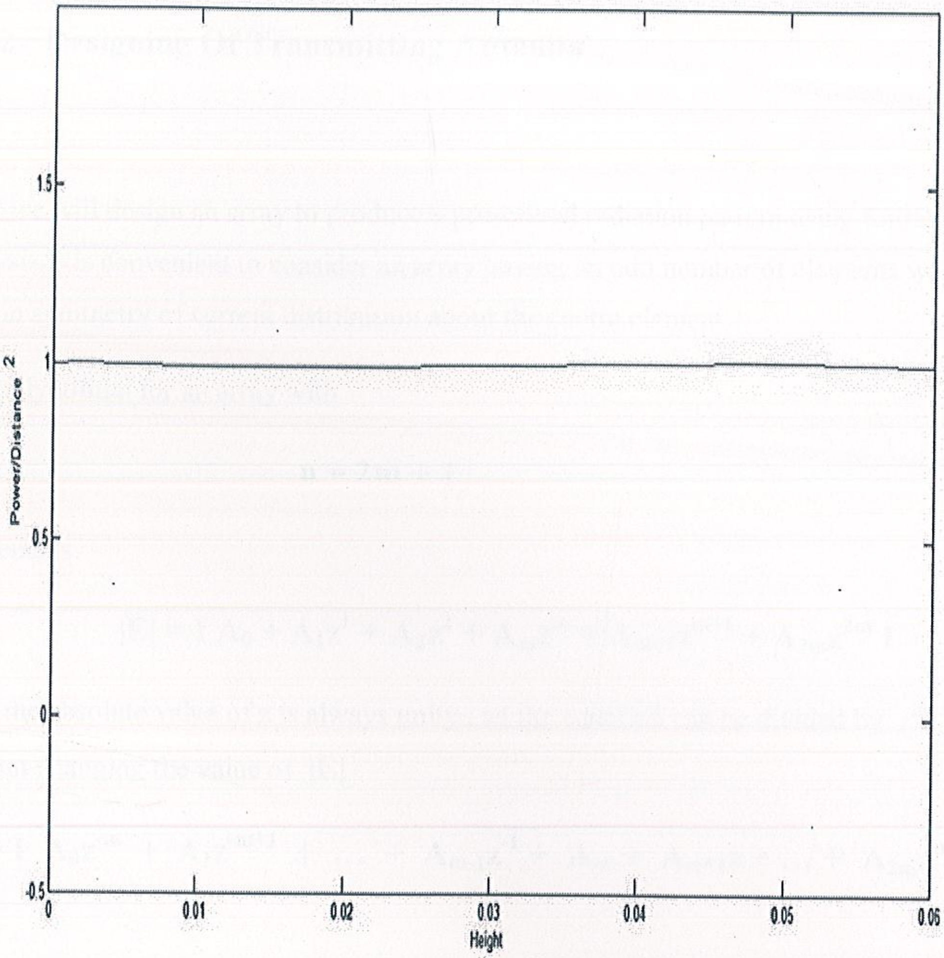

Fig 4.12 Graph of Net power/distance^2 Vs Height

We have seen in the last result table that the objective to keep the power same throughout its glide path is obtained

4.4.2 Designing Of Transmitting Antenna

Now we will design an array to produce a prescribed radiation pattern using fourier analysis.It is convenient to consider an array having an odd number of elements with a certain symmetry of current distribution about the centre element

The polynomial for an array with

$$n = 2m + 1$$

elements is

$$|E| = I\ A_0 + A_1 z^1 + A_2 z^2 + A_m z^m + A_{m+1} z^{m+1} + A_{2m} z^{2m}\ I$$

Now the absolute value of z is always unity , so the equation can be divided by z^m without changing the value of $|E|$

$$|E| = I\ A_0 z^{-m} + A_1 z^{-m+1} + \ldots + A_{m-1} z^{-1} + A_m + A_{m+1} z + \ldots + A_{2m} z^m\ I$$

It is now specified that the currents in corresponding elements on either side of the center element be equal in magnitude, but that the phase of the left side element shall lag that of the center element by the same amount that the corresponding right side element leads the center element

That is , the coefficients of corresponding elements are made complex conjugates with

$$A_m = a_0 \qquad A_{m-k} = a_k - j\,b_k$$

$$A_{m+k} = a_k + j\,b_k$$

Then the sum of terms of two corresponding elements may be written as

$$A_{m-k}z^{-k} + A_{m+k}z^{k} = a_k(z^{k} + z^{-k}) + jb_k(z^{k} - z^{-k})$$

$$= 2a_k \cos(k\Psi) - 2b_k \sin(k\Psi)$$

$$z^{k} = e^{jk\Psi}$$

The expression for $|E|$ is now

$$|E| = 2[a_0/2 + a_1 \cos\Psi + \ldots + a_m \cos m\Psi - (b_1 \sin\Psi + \ldots + b_m \sin m\Psi)]$$

$$|E| = 2\ \{a_0/2 + \quad [a_k\cos(k\Psi) - b_k \sin(k\Psi)\ ]\}$$

Putting the corresponding values in the electric field equation we get

$$a_0 = ½$$

$$a_k = 1/k\pi(\sin k\pi/60)$$

$$b_k = 0$$

Further the Equation now becomes,

$$|E| = (1/\pi)(0.052)\ |\ (1/3)z^{-3} + z^{-1} + \pi/2 + z + (1/3)z^{3}\ |$$

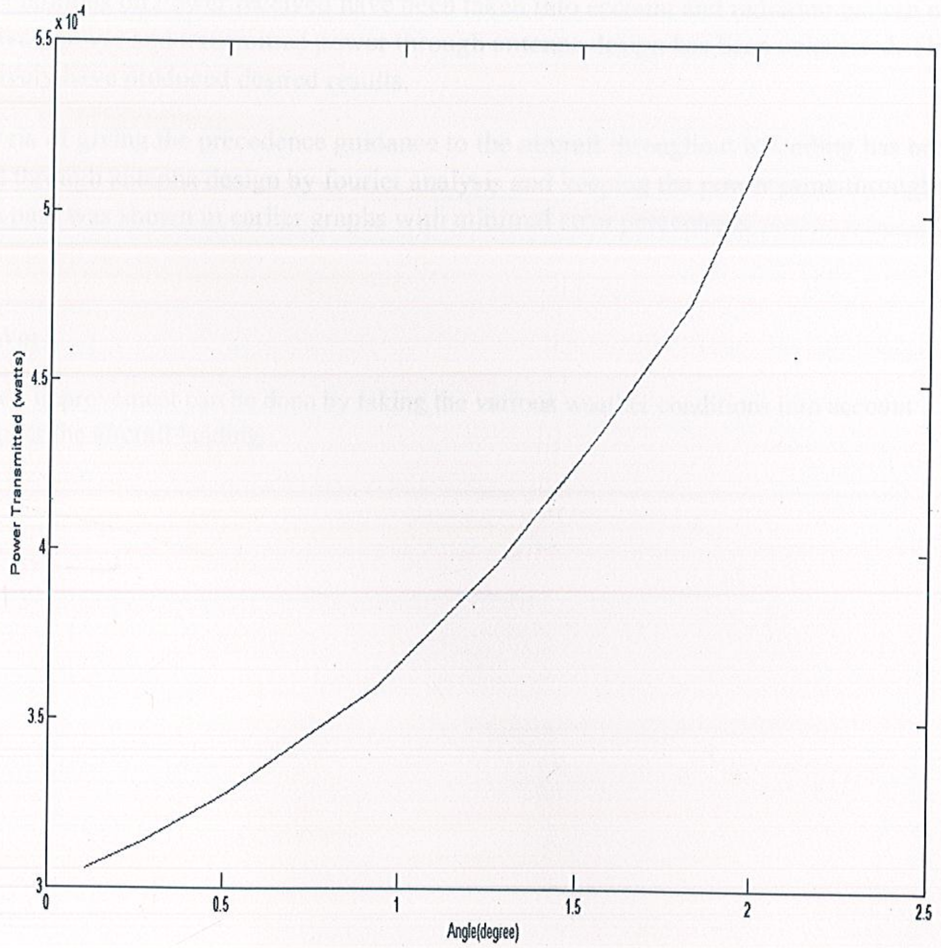

Fig 4.13 Graph of Net Power Transmitted Vs Angle

Chapter 5

Conclusion

All the conditions on Power received have been taken into account and radiation pattern of net received power and transmitted power through antenna design has been calculated. They cumulatively have produced desired results.

The criteria of giving the precedence guidance to the aircraft throughout is landing has been achieved through antenna design by fourier analysis and keeping the power same throughout the glide path was shown in earlier graphs with minimal error percentage.

Future Work

The further improvement can be done by taking the various weather conditions into account which hinder the aircraft landing.

Chapter 6

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